



88007314

FINAL REPORT

ON

BLM CONTRACT NO. BLM AA 851-CTI-48

(Cryptogamic Soil Crusts on Arid and Semiarid Rangelands in Utah:
Effects on Seedling Establishment and Soil Stability)

February 24, 1985

Kinball T. Harper and Larry L. St. Clair

Department of Botany and Range Science
Brigham Young University
Provo, Utah 84602

S
623
.H37
1985

FINAL REPORT

ON

BLM CONTRACT NO. BLM AA 851-CTI-48

(Cryptogamic Soil Crusts on Arid and Semiarid Rangelands in Utah:
Effects on Seedling Establishment and Soil Stability)

February 24, 1985

Kimball T. Harper and Larry L. St. Clair

Department of Botany and Range Science
Brigham Young University
Provo, Utah 84602

S
623
.H37
1985

1971-1972

1971

1971-1972

1971-1972

1971-1972

1971-1972

1971-1972

1971-1972



United States Department of the Interior

BUREAU OF LAND MANAGEMENT
UTAH STATE OFFICE
324 SOUTH STATE, SUITE 301
SALT LAKE CITY, UTAH 84111-2303

IN REPLY REFER TO

1740/7000
(U932)

MAY 20 1935

Memorandum

To: Director BLM (W-201) (Room 5654)
(W-852) (Room 2444)

From: State Director

Subject: Final Report on "Cryptogamic Soil Crusts on Arid and Semiarid Rangelands in Utah: Effects on Seedling Establishment and Soil Stability" (Contract AA 851-CT1-48)

We are forwarding the final report on the subject contract. Results of this study show that the control plots with intact cryptogamic cover had 2.82 and 1.62 times as many seedlings as the scalped plots after one and three years respectively. Not all vegetative species seeded benefited from the cryptogams, however. Effects of trampled and scalped treatments compared to the plots with undisturbed cryptogamic cover are:

<u>Treatment</u>	<u>Runoff</u>	<u>Soil Movement</u>
Trampled	52% more	514% more
Scalped	92% more	1,341% more

Cryptogamic cover significantly reduced water runoff, soil movement, and caused roughened soil surfaces for improved watershed conditions.

Other observations which the researchers provided during a review meeting on the final report were:

1. In low precipitation areas receiving comparable precipitation distribution, there is a tendency for better cryptogamic crust development in relation to vascular plants on clayey and silty soils. Vascular plants are favored under the above conditions on sandy soils. Cryptogams are found in significant amounts in sandy soils in areas receiving more summer precipitation.

1965-1966
1965
1965

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
UTAH STATE OFFICE
150 SOUTH STATE STREET
SALT LAKE CITY, UTAH 84111



MAY 2 1965

MEMORANDUM

TO: DIRECTOR, BLM (101) (Room 101)
FROM: (101-101) (Room 101)

State Director

SUBJECT:

Final Report on "Hydroponic Soil" Tests on Salt and
Saturated Soil. Results in Utah. Effects on Seedling Establishment
and Soil Properties. (Contract No. 551-1-43)

The following is the final report on the subject contract. Results of
this study show that the control plot with intact orogenic crust had
a 50% increase in seedling establishment as compared to the other two and
that the control plot had a 50% increase in seedling establishment as
compared to the other two. The results of the study show that the
control plot had a 50% increase in seedling establishment as compared to
the other two. The results of the study show that the control plot had
a 50% increase in seedling establishment as compared to the other two.

Soil - (Hydroponic)
1. 101-101
1. 101-101

Soil - (Hydroponic)
1. 101-101
1. 101-101

Soil - (Hydroponic)
1. 101-101
1. 101-101

Development of the "Hydroponic Soil" Tests on Salt and
Saturated Soil. Results in Utah. Effects on Seedling Establishment
and Soil Properties. (Contract No. 551-1-43)

Development of the "Hydroponic Soil" Tests on Salt and
Saturated Soil. Results in Utah. Effects on Seedling Establishment
and Soil Properties. (Contract No. 551-1-43)

Development of the "Hydroponic Soil" Tests on Salt and
Saturated Soil. Results in Utah. Effects on Seedling Establishment
and Soil Properties. (Contract No. 551-1-43)

2. Cryptogams appear to be as important as vascular plants in providing soil stabilizing vegetative cover in desert ecological sites.

Our research and development proposal (dated 3/21/85) on "Ecology and Cryptogamic Crusts" covers future research which is needed for our understanding of the significance of cryptogams to Grazing, Watershed, and Habitat Management programs. Information areas to be improved or expanded are:

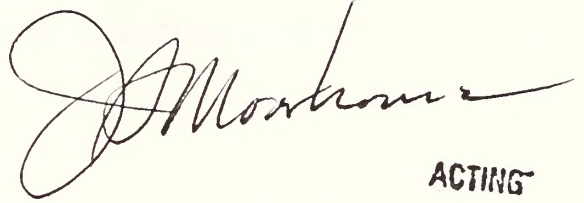
Proposal No. 1 will document the influence of cryptogams on germination and survival of 10 major forage soil stabilizing species. This proposal builds on germination and seedling establishment trial results obtained in the attached final report. Here Elymus junceus performed better on scalped plots. Also Ceratoides lanata and Linum perenne establishment on the control plots was not statistically better than on the scalped plots. While the overall results of cryptogamic crusts were favorable for vascular plant seed germination and establishment, certain species were affected negatively or not improved. Further research is needed to determine effects on more of the important vegetative species in BLM's Watershed, Grazing, and Habitat Management programs. Species to be seeded would include: four wing saltbush, "Hycrest" crested wheatgrass, Indian ricegrass, pubescent wheatgrass, etc.

These trials would also be replicated in the Colorado Plateau province where summer rains influence cryptogamic cover differently than in the Great Basin (low in summer rain).

Proposal No. 2 will determine the effects of different intensities and season of winter sheep grazing on cryptogamic crusts. Grazed pastures on the Great Basin Experimental Station will provide the opportunity to determine the effect of controlled winter grazing on cryptogamic cover. It is imperative that this segment of the research proposal be accomplished this year since the U. S. Forest Service will discontinue their operation of the station and grazing systems, etc. could be changed. Results from these pastures will determine the amount of degradation of cryptogamic crust on Great Basin ranges from winter sheep grazing.

The last proposal (No. 3) will assess the effect of artificial inoculation of cryptogamic crusts on vascular plant seedling establishment and survival. Understanding how to inoculate with cryptogams and assessing the effect of this inoculation is an important action which we believe needs to be started this year. Results from the attached final report show that bluegreen algae establish themselves quickly and abundantly. This can be critical for stabilizing sites which are subject to wind erosion following wildfires.

We believe these researchers are most knowledgeable in cryptogamic crust ecology and will provide some important information for improving our management programs. These results have Bureau wide application to Grazing, Watershed, and Habitat Management programs.

A handwritten signature in dark ink, appearing to read "J. Montague", with a long horizontal flourish extending to the right.

ACTING

Enclosures - 1

1 Final Report - Contract No. AA 851-CT1-48

8900737

H37
1985

CONTENTS

	<u>Page</u>
SUMMARY	3
EFFECTS OF CRYPTOGAMIC COVERS ON SEEDLING ESTABLISHMENT . . .	5
Methods	5
Results	5
Response of Vascular Plant Seedlings	9
Relative Effects of Algae, Lichens and Mosses	15
EFFECTS OF CRYPTOGAMS ON WATER RUNOFF AND SOIL STABILITY . . .	18
Methods	18
Results	23
Discussion.	28
Conclusions	
OTHER RESEARCH ACTIVITIES	
Artificial Establishment of Cryptogams.	
Cryptogams and the Nitrogen Cycle	
Evaluation of Health of Lichen Thalli	
LITERATURE CITED	

Bureau of Land Management
Library
Bldg. 50, Denver Federal Center
Denver, CO 80225

CONTENTS

Page

1	INTRODUCTION
2	STATE OF CALIFORNIA, DEPARTMENT OF LAND MANAGEMENT
3	DESIGNATION OF LANDS
4	LANDS OF THE STATE
5	LANDS OF THE COUNTY
6	LANDS OF THE CITY
7	LANDS OF THE TOWNSHIP
8	LANDS OF THE PARISH
9	LANDS OF THE DISTRICT
10	LANDS OF THE TERRITORY
11	LANDS OF THE NATION
12	LANDS OF THE WORLD
13	LANDS OF THE UNIVERSE
14	LANDS OF THE GODS
15	LANDS OF THE DEVILS
16	LANDS OF THE ANGELS
17	LANDS OF THE SAINTS
18	LANDS OF THE SINNERS
19	LANDS OF THE DEAD
20	LANDS OF THE LIVING

FINAL REPORT

Cryptogamic Soil Crusts on Arid and Semiarid Rangelands in Utah:

Effects on Seedling Establishment and Soil Stability

SUMMARY

The influence of soil cryptogamic covers on emergence and survival of seedlings of seven useful range plants (Ceratoides lanata, Elymus junceus, Kochia prostrata, Oryzopsis hymenoides, and Sphaeralcea coccinea) was experimentally evaluated at three sites in Central Utah. Species were randomly assigned to plots and plots were randomly assigned to control or treatment classes. Treated plots had the cryptogamic layer along with the surface centimeter of soil scalped away. At each site, 36 seeds of each of 5 seed plants were sown through a template onto 10 experimental plots. Each plot was 0.75 m x .75 m; the scalping treatment was randomly assigned within each set of 10 plots for each vascular species tested. Results showed that the average control plot (cryptogamic cover intact) had 2.82 times as many seedlings as the average scalped plot, one year after planting. After 3 years, the average control plot still had 1.62 times as many surviving seedlings as the average scalped plot. Two species had no surviving seedlings after 3 years (Ceratoides lanata and Lepidium montanum). Seedlings of the other five species all survived best on plots on which the cryptogamic cover had been left in place.

The influence of undisturbed cryptogamic covers on water runoff and soil movement was tested at one site in Utah County (Camp Floyd at Fairfield). Small plots (0.25 m^2) were subjected to artificial rain using a pipette infiltrometer. Treatment plots were delimited by a metal frame which channeled runoff water and sediments into collecting

vessels. Rain was applied at the rate of about 5 cm in an 8-minute interval. Plots were located in a Sarcobatus vermiculatus - Atriplex confertifolia stand having heavy cryptogamic cover in interspaces between shrubs. Plots were placed in interspaces so as to minimize the effects of vascular plants. Three treatments were applied to plot surfaces: 1) no modification of the cryptogamic cover (control); 2) simulated trampling of the surface; and 3) removal of the cryptogamic layer with the associated surface centimeter of soil using a "square-mouthed" shovel. Results show that trampling increased water runoff 52% and soil movement 514% relative to the control. Scalping away the cryptogamic crust increased runoff 92% and soil movement 1,341% relative to the control. Regression analysis demonstrated that cryptogamic cover significantly reduced water runoff and soil erosion. Lichen and moss cover had greater impacts on watershed quality than bluegreen algal cover alone, but inclusion of algal cover with lichen and moss cover greatly strengthened the regression model for water runoff. The tendency of all cryptogams to roughen soil surfaces appears to be an important influence for improved watershed conditions.

Preliminary results demonstrate that it is possible to artificially inoculate unstable surfaces with cryptogamic plants. Bluegreen algae especially established quickly and in abundance. Our vascular plant seedling results suggest that the bluegreen algae are more likely to facilitate vascular plant seedling establishment than either lichens or mosses. Others (Schlatterer and Tisdale 1969) have reported that the moss Tortula actually interferes with establishment of seedlings of some range grasses.

EFFECTS OF CRYPTOGAMIC COVERS ON SEEDLING ESTABLISHMENT

Methods

Our trial plantings were designed to test the effects of cryptogamic crusts on germination and survival of a variety of domestic and range forage species. Seeds of each test species were planted at precisely known locations by use of a plywood template. At a given location, each test species was planted at 36 fixed locations on each of 10 plots, each 0.75 m x 0.75 m. At each planting site, a coin was tossed to determine whether the surface cm of crust was to be removed or left in position. After that choice was made, the planting template was placed over the plot, two metal pegs were driven through holes in opposite corners of the template to permit repositioning at the exact spot for observations on germination and survival, and finally 36 seeds of the test species were planted through holes in the template. A total of five species were planted at each site and each species was replicated 10 times. The planting design was based on 5 rows of 10 plots each (plots are 0.75 m x 0.75 m). An 0.5 m wide access path was left between each pair of rows. All seedings were completed prior to December 20, 1981.

Results

The planting plots in Utah, Juab, and Emery Counties were reinventoried for vascular plant seedling establishment in 1982, 1983 (except for the BLM-USU pasture site), and 1984 . .

The nature of the cryptogamic cover on the three sites used to evaluate the impact of such cover (if any) on establishment of vascular plant seedlings is reported in Table 1. Cryptogamic cover averaged from

Table 1. General characteristics of the cryptogamic cover at the three sites analyzed for the effects of cryptogams on establishment of vascular plant seedlings.

Characteristic or species	Sites		
	Buckhorn Reservoir	Tintic Junction	BLM-USU Pasture
Average cryptogamic cover (%)	31.3	30.3	23.1
Relative composition of cover			
Bluegreen algae (%)	55.6	74.6	12.1
Mosses (%)	8.9	18.5	76.2
Lichens (%)	35.6	6.9	11.7
<u>Species frequency in 0.56 m² quadrats (%)</u>			
Bluegreen algae	73.1	100.0	65.0
Mosses:			
<u>Bryum sp.</u>	0	19.2	0
<u>Grimmia sp.</u>	65.4	15.4	12.5
<u>Phascum cuspidatum</u>	38.5	0	0
<u>Tortula ruralis</u>	0	80.8	100.0
Lichens:			
<u>Agrestia hispidia</u>	0	3.8	75.0
<u>Caloplaca citrina</u>	0	46.8	0
<u>Collema tenax</u>	88.5	100.0	T
<u>Dermatocarpon hepaticum</u>	38.5	15.4	100.0
<u>Endocarpon sp.</u>	0	50.0	0
<u>Fulgensia sp.</u>	15.4	0	37.5
<u>Lecanora sp.</u>	0	19.2	0
<u>Lecidea decipiens</u>	23.1	0	0
<u>Toninia caeruleonigricans</u>	11.5	0	0
<u>Average cover by species (%)</u>			
Bluegreen algae	16.8	22.6	2.7
Mosses:			
<u>Bryum sp.</u>	0	.1	0
<u>Grimmia sp.</u>	1.6	0.5	0.5
<u>Phascum cuspidatum</u>	0.2	0	0
<u>Tortula ruralis</u>	0	5.0	17.1
Lichens:			
<u>Agrestia hispidia</u>	0	T	0.1
<u>Caloplaca citrina</u>	0	T	0
<u>Collema tenax</u>	15.5	1.9	T
<u>Dermatocarpon hepaticum</u>	1.4	T	2.6
<u>Endocarpon sp.</u>	0	0.1	0
<u>Fulgensia sp.</u>	T	0	0
<u>Lecanora sp.</u>	0	0.1	0
<u>Lecidea decipiens</u>	T	0	0
<u>Toninia caeruleonigricans</u>	T	0	0

23 to 31 percent: bluegreen algae dominated the cover at both the Tintic Junction (Juab County) and the Buckhorn Reservoir site (Emery County). The cryptogmic cover at the BLM-USU Pasture site was the most sparse encountered (23%) and dominated by mosses. Lichen cover was best represented at the Buckhorn Reservoir (about 1/3 of 31% total cover).

To evaluate the chemical and physical effects associated with scalping plots to remove the cryptogams, a composite surface sample (approximately the surface 1.0 cm) was taken from plots seeded to vascular species that showed good establishment (some species failed to produce seedlings and their plots were not sampled). The results (Table 2) show that scalping had no significant effect on soil texture. Furthermore, although scalped plots, on the average, show less nitrogen than controls at all three sites, the differences were small and statistically nonsignificant. Soil reaction, electrical conductivity, and extractable phosphorus (extracted by 0.2 N acetic acid) differed significantly between control and scalped plots at all sites (Table 2). Soil reaction was invariably more basic on scalped plots, while electrical conductivity (salinity) was less. Both results are probably related to the fact that soils were scalped in late autumn 1981, after soluble salts (undoubtedly rich in sodium chloride, a neutral salt) had been concentrated at the soil surface by evaporation during the late summer which was dry at all sites in 1981.

Results for phosphorus are difficult to explain: that element was most abundant on scalped plots at two sites (Buckhorn Reservoir and Tintic Junction) and on control plots at BLM-USU pasture. The results may reflect the common tendency of cryptogamic crusts to collect windblown materials which may differ in content of phosphorus from residual material below the aeolian enriched surface layer.

Table 2. Some chemical and physical characteristics of surface (top 1.0 cm) soils of scalped and control plots at the three sites used in the planting trials. Sample size is given for each site. Means for any variable and site that do not differ significantly between treatment and control plots are followed by the same letter in superscript.

Variable	Sites		
	Buckhorn Reservoir	Tintic Junction	BLM-USU Pasture
Sample Size			
Control	9	8	12
Scalped	11	12	8
pH			
Control	8.0 ^a	7.3 ^a	7.6 ^a
Scalped	8.2 ^b	7.5 ^b	7.8 ^a
Electrical Conductivity			
Control (millimhos x 10 ³)	1.7 ^a	.9 ^a	1.1 ^a
Scalped (millimhos x 10 ³)	1.1 ^a	.7 ^b	.7 ^b
Extractable phosphorus			
Control (ppm)	32.2 ^a	40.9 ^a	108.6 ^a
Scalped (ppm)	40.3 ^b	59.5 ^b	101.4 ^b
Total nitrogen			
Control (%)	.059 ^a	.088 ^a	.071 ^a
Scalped (%)	.039 ^a	.087 ^a	.062 ^a
Organic matter			
Control (%)	1.15 ^a	1.33 ^a	1.41 ^a
Scalped (%)	.58 ^a	1.52 ^a	1.46 ^a
Sand			
Control (% by wt.)	65.8 ^a	32.7 ^a	47.7 ^a
Scalped (% by wt.)	66.0 ^a	34.1 ^a	49.5 ^a
Soil depth ²			
Control (cm)	23.0 ^a	---	44.0 ^a
Scalped (cm)	22.7 ^a	---	40.1 ^a

1. Extracted with 0.2 N acetic acid

2. Actually penetrability with a sharpened 1.0 cm diameter steel rod.

Response of Vascular Plant Seedlings

The species seeded at the three sites and the treatment of seeded plots are reported in Tables 3 and 4. Three species (Artemisia tridentata, Chrysothamnus viscidiflorus and Oryzopsis hymenoides) either failed to germinate or had very few seedlings that survived until summer 1984. A. tridentata was seeded at Tintic Junction and BLM-USU Pasture, C. viscidiflorus was sown at Tintic Junction, and O. hymenoides was sown at both Buckhorn reservoir and BLM-USU Pasture. As a result, 50 of the 150 plots seeded yielded no usable data. On the remaining plots, there were 2.8 times as many surviving seedlings on control as on scalped plots after one year (Table 4). That general result was observed at all planting sites; the advantage exhibited by control plots ranged from a low of 1.85 at Tintic Junction to almost 4.3 at the BLM-USU Pasture site. The differences between control and scalped plots in respect to seedling establishment (species ignored) was statistically significant at all three sites.

Three species (Kochia prostrata, Lepidium montanum, and Sphaeralcea coccinea) showed markedly better seedling establishment on control plots with the pattern being statistically significant at at least one planting site (Tables 4 and 5). Two other species (Ceratoides lanata and Linum perenne) establish more seedlings on control than on scalped plots, but the differences were not statistically significant. Only Elymus junceus appeared to perform best on scalped plots.

Surviving seedlings at the three sites are reported for 1983 and 1984 in Table 6. After three years there were still 1.62 times more seedlings on the average control plot than on the average scalped plot. On all sites all seedlings of one species that had initially germinated well died (Lepidium montanum at Buckhorn Reservoir, Sphaeralcea coccinea at BLM-USU Pasture, and Kochia prostrata at Tintic Junction). However, where the species had surviving seedlings after three years, survival was always better on control plots where the cryptogamic layer had been left intact (Table 7).

Table 3. Summary of treatments and species planted on plots established at the three sites. Each species was planted on 10 plots at each site. Species and treatments (control or scalped) were randomly assigned at each plot. There were 50 plots per site.

Site and species	Treatment	
	Scalped	Control
Buckhorn Reservoir	no. plots	
<u>Elymus junceus</u>	4	5
<u>Kochia prostrata</u>	5	6
<u>Lepidium montanum</u>	5	5
<u>Oryzopsis hymenoides</u>	6	4
<u>Sphaeralcea coccinea</u>	6	4
Tintic Junction		
<u>Artemisia tridentata</u>	7	3
<u>Chrysothamnus viscidiflorus</u>	1	9
<u>Elymus Junceus</u>	7	3
<u>Kochia prostrata</u>	7	3
<u>Linum perenne</u>	5	5
BLM-USU Pasture		
<u>Artemisia tridentata</u>	7	3
<u>Ceratoides lanata</u>	3	7
<u>Elymus junceus</u>	7	3
<u>Oryzopsis hymenoides</u>	6	4
<u>Sphaeralcea coccinea</u>	5	5
Total	53	47

Table 4. Number of seedlings established after one year at each planting site and under each treatment (control or scalped of cryptogamic crust). The two treatments were randomly assigned to all plots at each site. At each plot 36 seeds were sown through holes in a template to facilitate relocation of exact planting points.

Site and species	Scalped	Control	Significance of difference ¹
Buckhorn Reservoir			
Ave. no. seedlings per plot after one year			
<u>Elymus junceus</u>	1.8	0.4	p < .05
<u>Kochia prostrata</u>	0.0	0.3	ns
<u>Lepidium montanum</u>	1.6	10.0	p < .01
<u>Sphaeralcea coccinea</u>	2.0	5.5	p < .01
Average/plot	1.35	4.05	p < .01
Tintic Junction			
<u>Elymus junceus</u>	0.1	0.0	ns
<u>Kochia prostrata</u>	1.6	4.0	p .01
<u>Linum perenne</u>	2.2	3.2	ns
Average/plot	1.30	2.40	p < .01
BLM-USU Pasture			
<u>Ceratoides lanata</u>	0.3	0.6	ns
<u>Oryzopsis hymenoides</u>	0.2	0.0	ns
<u>Sphaeralcea coccinea</u>	1.6	8.4	p < .01
Average/plot	0.70	3.00	p < .01

1. The test statistic was Chi-square. The analysis tested success of individual plantings in control and scalped plots.

Table 5. Total number of seedlings of each species surviving at each site and under each treatment after one year. The number of plots at each site that had living seedlings at the end of the first year is also given in parentheses for each treatment.

Site and species	Treatment	
	Scalped	Control
Buckhorn Reservoir	No. Seedlings (no. plots with seedl.)	
<u>Lepidium montanum</u>	8 (3)	50 (4)
<u>Sphaeralcea coccinea</u>	12 (3)	22 (4)
Other	7 (3)	4 (4)
Tintic Junction		
<u>Kochia prostrata</u>	11 (4)	12 (3)
<u>Linum perenne</u>	11 (4)	16 (5)
Other	1 (1)	0 (0)
BLM-USU Pasture		
<u>Ceratoides lanata</u>	1 (1)	4 (3)
<u>Sphaeralcea coccinea</u>	8 (4)	42 (5)
Other	1 (1)	0 (0)
Total seedlings and plots with seedlings	60 (24)	150 (28)
Total plots in sample	53	47

Table 6. Number of seedlings surviving at each site in 1983 and 1984.
The BLM-USU Pasture site was not inventoried in 1983.

Site, species and treatment	1983 Average Number	1984 Seedlings/Plot
Buckhorn Reservoir		
<u>Elymus junceus</u>		
Control	0.4	0.4
Scalped	1.8	0.3
<u>Kochia prostrata</u>		
Control	0.2	0.0
Scalped	0.2	0.0
<u>Lepidium montanum</u>		
Control	10.0	0.0
Scalped	1.6	0.0
<u>Sphaeralcea coccinea</u>		
Control	5.5	2.0
Scalped	2.0	0.3
Tintic Junction		
<u>Elymus junceus</u>		
Control	0.0	0.0
Scalped	0.1	0.0
<u>Kochia prostrata</u>		
Control	0.0	0.0
Scalped	0.0	0.0
<u>Linum perenne</u>		
Control	3.4	3.0
Scalped	2.8	2.2
BLM-USU Pasture		
<u>Ceratoides lanata</u>		
Control	---	0.0
Scalped	---	0.0
<u>Elymus junceus</u>		
Control	---	0.3
Scalped	---	0.0
<u>Oryzopsis hymenoides</u>		
Control	---	0.3
Scalped	---	0.5
<u>Sphaeralcea coccinea</u>		
Control	---	0.0
Scalped	---	0.0

Table 7. Percentage survival of seedlings by summer 1984. Percentage survival on scalped and control plots was based on all seedlings known to have resulted from our plantings on those plots. Species are ignored where all seedlings died on both treatment and control plots.

Site and Species	Plot treatment	
	Scalped	Control
	% Survival	
Buckhorn Reservoir		
<u>Elymus junceus</u>	14	100
<u>Sphaeralcea coccinea</u>	17	27
Tintic Junction		
<u>Linum perenne</u>	79	88
BLM-USU Pasture		
<u>Elymus junceus</u>	0	100
<u>Oryzopsis hymenoides</u>	75	100

Relative Effects of Algae, Lichens and Mosses

The first year data suggest that the three major groups of autotrophs involved in the cryptogamic crusts do not affect vascular plant seedlings alike (Table 8). Our preliminary results (taken at only one of the three study areas) indicate that bluegreen algae and lichens are more beneficial (or less detrimental in the case of species which establish best on scalped sites) than mosses in the process of seedling establishment. Schlatterer and Tisdale (1969) have also concluded that moss tissue has a depressing effect on seed germination of Agropyron spicatum, Sitanion hystrix and Stipa thurberiana under greenhouse conditions. If that generalization holds up at other sites and with other species, cryptogamic crusts will have to be considered more seriously than they have been in the past in range management.

Earlier studies (Anderson et al. 1982 a,b,) have shown that bluegreen algal crusts are more resistant to trampling of grazing animals than either lichen or moss. Thus algal crusts are more likely to persist under the impact of grazing and can probably be successfully managed under some modification of grazing systems currently in use. If algal crusts can be maintained on the arid range lands of our region, it is likely that they will affect as much or more of the soil surface as vascular plant which we have focused management attention on in the past. The literature suggests that maintenance of algae crusts on rangelands should improve soil fertility (Fletcher and Martin 1948, MacGregor and Johnson 1971, Rychert and Skujins 1974, Kleiner and Harper 1972, Brotherson and Rushforth 1983), and reproductive success of at least many of the vascular components of the regional rangelands (this report).

Table 8. Relative effects of algal, moss, or lichen cover on establishment of seedlings of Elymus junceus, Lepidium montanum and Sphaeralcea coccinea at the Buckhorn Reservoir site, Emery County. Linear regression is the test by which the effects of variable amounts of each type of cryptogamic cover on seedling establishment is evaluated.

Type of Cover	Species		
	<u>Elymus</u> <u>junceus</u>	<u>Lepidium</u> <u>montanum</u>	<u>Sphaeralcea</u> <u>coccinea</u>
Correlation coefficients			
Bluegreen algae	-.23	.84**	.77**
Lichens	-.40	.75*	.87**
Mosses	-.47	-.14	.17
Total Cryptogamic	-.31	.74*	.85**

*p <.05

**p <.01

Correlation coefficients that are not starred are not statistically significant.

Our data for the cryptogamic cover on soil burned over in 1978 in the Camp Floyd Military Cemetery shows that bluegreen algal cover had recovered greatly by 1982 and was by then almost equal to that on adjacent unburned sites. In addition, two lichen species were rapidly invading the burn: Collema tenax and Caloplaca Citrina are now common on the burn, but still produce much less cover than on adjacent unburned areas. Both species produce numerous tiny soredia on the thallus and are apparently wind dispersed onto the burned area. Thus, whether the disturbance is grazing or fire, bluegreen algal crust components recover rapidly.

EFFECTS OF CRYPTOGAMS ON WATER RUNOFF AND SOIL STABILITY

In August of 1983, 30 plots were established for evaluation of the influence of cryptogamic crusts on surface runoff and associated soil loss. The plots were placed in an undisturbed, ungrazed corner of the Cemetery at Camp Floyd, Fairfield Utah (Utah County).

Methods

Each plot was 0.25m^2 in size. A custom-made steel frame was used to circumscribe the experimental plot and channel runoff to an outflow point where it could be collected, volume determined, and sediments removed, dried and weighed. The frame was sharpened on the bottom edge, so that it could be forced into the soil to a depth that placed the outflow channel flush with the soil surface. A collection pit large enough to hold a 1.5 liter plastic container was dug beneath the outflow channel at each plot.

Five treatments were applied: 1) control (no modification of surface), 2) trampling to simulate the hooves of grazing animals, 3) trampling with an immediate, uniform application of 1.0 cm of distilled water over the surface of the plot, 4) trampling with immediate application of distilled water in which chlorox bleach had been dispersed at a rate of 1.0 ml/liter in order to kill soil algae, and 5) removal of the surface 4-6 mm of soil with a square mouthed shovel so as to eliminate plant cover and leave a uniform surface (hereafter called scalping). Six replicates of each treatment were taken with all treatments being applied within each of six local areas of no more than 25m^2 each. Each local area was selected for uniformity of vegetative cover (vascular and nonvascular), topography, and soil. The 6 local sample areas were distributed throughout an area about 1.0 ha in size.

The original intent of treatment 2 (trampling alone) was to crush the roughened surface and break up any natural binding of soil particles by filaments and gelatinous secretions from the cryptogamic plants. In this treatment, we hoped to separate the effects of organic debris alone from those of an undisturbed cryptogamic "veneer" that both roughened and aggregated the surface. Treatment 3 (trampling + immediate application of 1.0 cm of water) was intended to reveal approximately how much of the effect of an original cryptogamic crust could be restored by a single storm that dropped 1.0 cm of moisture. Treatment 4 (trampling + water + chlorox) was an attempt to separate the runoff and erosion inhibiting effects of physical crusts associated with wetting and drying from regrowth of cryptogamic components of natural crusts: The Chlorox was intended to be toxic to plants but too dilute to cause disassociation of carbonates and enhanced hardness of physical crusts. Any possible differential effects of treatments 2, 3 and 4 were largely eliminated by a heavy (over 5.0 cm) natural rainstorm the week following preparation of the plots. Marked greening of algae and mosses on plots treated with Chlorox demonstrated that 1.0 ml of Chlorox per liter of water was too dilute a solution to inhibit growth of at least some cryptogamic species. The storm also necessitated postponement of treatment with artificial rain until the soils had dried to levels more representative of summer conditions in the area. Thus several weeks separated preparation of plots and final treatment with artificial rain.

Vegetation at the general study site is dominated by greasewood (Sarcobatus vermiculatus). Shadscale (Atriplex confertifolia), winterfat (Ceratoides lanata) and greenmolly (Kochia americana) are occasional associates. Three grasses (Agropyron dasystachyum, Bromus

tectorum, and Sitanion hystrix) are common in the understory of the shrub stand with their cover being greatest near and beneath shrubs. Interspace area well removed from shrubs supported little vascular plant cover, but often carried relatively heavy nonvascular cover. Overall, vascular plant cover averaged between 30 and 40 % in the study area, but our experimental plots were purposely placed in interspaces where almost all cover was nonvascular.

Trampling was simulated by running a dandelion digger horizontal to and about 1.0 cm under the dry surface. The plot (delimited by the metal frame) was then stepped on by an adult weighing about 84 kg. Each part of the plot surface was stepped on twice with the second set of tread marks running at right angles to the first. Due to the dry conditions prevailing at the time plots were established, cryptogamic crusts were completely disrupted by the preceding treatment, leaving a relatively smooth surface. Control plots had rough surfaces that were darkened by bluegreen algal filaments and the black lichen, Collema tenax, the commonest lichen at the site.

Occasionally the annual, Bromus tectorum, or native wheatgrass were unavoidable in placement of plots, but no other vascular plants occurred within the plots and grass cover was always less than 10%. When shrubs occurred near plots, crowns were pruned to eliminate interference with placement of the metal frame and the artificial rain device. When grasses were present on the plots, above-ground stems were clipped away at ground level and removed from the plot, but grass crowns and roots were left in place on all but the scalped plots. On scalped plots, crowns of such grass plants as were present were largely removed in the scalping process, but their roots remained. Unfortunately, grass cover

Table 9. Runoff and soil erosion from 0.25 m² experimental plots at Camp Floyd, Fairfield, Utah. Treatment applied to each plot, its cryptogamic cover, surface roughness, soil texture, surface slope, sodium content of surface soil, and surface temperature at time of infiltration trial are also noted.

Plot No.	Treatment	Runoff (ml)	Soil loss (g)	Cover (%)		Soil texture (%)		Slope (%)	Na ⁺ (ppm)	Temperature (°C)	Surface roughness
				Total	Non-algal	Sand	Clay				
1	Control	6,150	3.3	38.0	3.0	23.0	26.2	1.8	46	22.2	3
2	Trampled	8,310	2.5	34.0	4.0	29.0	22.2	6.7	68	15.6	2
3	Trampled + H ₂ O	9,225	31.5	24.5	1.5	24.7	28.2	4.4	36	15.6	2
4	T + H ₂ O + Cl	7,250	5.0	38.0	3.0	30.7	22.2	9.8	69	21.7	2
5	Control	6,225	1.1	15.0	0.1	25.0	23.2	4.9	44	22.8	3
6	Trampled	7,200	6.3	17.0	2.0	30.7	22.2	11.1	53	15.6	2
7	T + H ₂ O	7,150	6.0	43.0	8.0	31.0	23.2	6.7	55	27.2	2
8	T + H ₂ O + Cl	10,000	2.3	59.0	24.0	25.0	27.2	0.0	51	26.1	2
9	Control	9,400	14.5	31.0	1.0	27.0	23.5	15.6	50	28.3	3
10	T + H ₂ O	11,125	104.6	30.0	10.0	26.5	24.1	15.1	51	13.9	2
11	T + H ₂ O + Cl	7,500	5.8	41.0	9.0	28.8	21.8	8.9	122	11.1	2
12	Trampled	9,700	152.4	39.0	9.0	26.9	23.9	16.4	135	15.0	2
13	Control	4,050	4.0	50.0	15.0	26.7	26.1	23.1	206	20.0	3
14	Trampled	7,575	12.7	59.0	24.0	27.0	26.0	22.2	142	16.1	2
15	T + H ₂ O	7,650	91.9	55.0	10.0	27.0	28.0	10.2	176	16.7	2
16	T + H ₂ O + Cl	8,475	61.1	41.0	15.0	31.0	21.9	10.2	122	21.1	2
17	Control	800	0.7	55.0	30.0	30.9	22.0	10.2	215	21.1	3
18	T + H ₂ O	4,475	7.1	87.0	82.0	33.0	22.1	7.6	107	21.1	2
19	Trampled	7,175	2.1	88.0	76.0	34.8	22.2	4.4	42	21.1	2
20	T + H ₂ O + Cl	8,525	23.9	66.0	36.0	24.7	24.2	7.1	291	20.0	2
21	Control	5,050	7.2	62.0	17.0	22.8	28.2	7.1	384	20.0	3
22	Trampled	7,900	33.8	58.0	18.0	26.7	22.1	12.4	81	24.4	2
23	T + H ₂ O	7,900	9.7	58.0	49.0	30.5	22.1	9.3	74	24.4	2
24	T + H ₂ O + Cl	7,375	4.3	37.0	21.0	30.4	22.2	4.9	117	24.4	2
25	Scalped	9,200	67.2	0.0	0.0	30.7	22.2	6.7	62	28.9	1
26	Scalped	10,500	11.7	0.0	0.0	26.7	24.1	0.0	38	23.3	1
27	Scalped	12,200	51.2	0.0	0.0	28.7	22.2	7.6	46	25.0	1
28	Scalped	9,400	44.8	0.0	0.0	21.0	29.0	2.2	124	18.3	1
29	Scalped	9,500	49.8	0.0	0.0	34.8	34.2	8.9	376	18.3	1
30	Scalped	9,900	216.5	0.0	0.0	27.0	30.0	4.9	95	24.4	1

All analyses were run in the Soil Analysis Laboratory, Brigham Young University.

Runoff from experimental plots was collected in 1.5 liter plastic containers. After sediments in runoff had settled for 24 hours, the clear water was decanted off and its volume determined. The remaining sediments were washed into a porcelain evaporating dish, heated to dryness and weighed.

Data were analyzed by analysis of variance and linear regression models. For regression analysis, surface roughness was assigned arbitrary values. The control was given a value of 3, trampled plots of treatments 2, 3 and 4 were assigned a value of 2, and scalped treatments were given a value of 1.

RESULTS

Soils in the study area are primarily silty clay loams with pH values that rarely depart by more than 0.1 of a unit from 8.0. Electrical conductivity ranged from 0.66 to 2.37 millimhos per cm with an overall average for the 30 plots of about 0.99 millimhos per cm. There were no significant differences among treatment groups for any of the foregoing variables.

Means and standard deviations by treatment class are presented for variables that are likely to have a significant effect on runoff and associated erosion in Table 10. Plot steepness (slope), soil temperature, soil texture and exchangeable sodium in the soil could not be demonstrated to differ significantly among treatments. Likewise, bluegreen algal cover (a component of total cryptogamic cover) failed to show significant differences among controlled and trampled treatments.

Table 10. Treatments applied and characteristics of experimental runoff plots at Camp Floyd Military Cemetery near Fairfield, Utah County, Utah. Plots were established and treatments applied Aug. 9, 1983. A 5.0 cm rainstorm swept the area during the following week and negated the effects of watering trials after trampling.

Treatment	No. Repli- cates	% Cover		Surface Plot slope roughness (%)	Soil Temp ¹ (°C)	Soil sand Soil clay Soil Na ⁺	
		Bluegreen algae	Other cryptogams			(%)	(%) (ppm)
Control	6	30.8a ±10.2	11.0ab ±11.8	10.5a ±7.8	22.4a ±3.1	25.9a ±3.0	24.9a ±2.3
Trample + water	6	24.0a ±13.8	26.8c ±31.9	8.9a ±3.7	19.8a ±5.3	29.0a ±3.6	24.6a ±2.8
Trample + water + chlorine	6	29.0a ±7.2	18.0bc ±11.7	6.8a ±3.9	20.7a ±5.2	28.4a ±2.9	23.3a ±2.1
Trample	6	26.2a ±13.4	22.2bc ±27.7	12.2a ±6.5	17.9a ±3.9	29.2a ±3.2	23.1a ±1.6
Scalped	6	0.0b ±0.0	0.0a ±0.0	5.1a ±3.4	23.1a ±4.1	28.2a ±4.6	27.0a ±4.9
				1			123a ±128

1. Temperature at time of infiltration-erosion trials. Trials were run on various days during the month of October.

However, nonalgal components (mosses plus lichens) of the cryptogamic crusts did show some significant differences among the nonscalped treatments (Table 10): Control plots had less moss and lichen cover than those of the trample plus water treatment but did not differ significantly from the other trampled treatments. The trampled treatments did not differ significantly among themselves in respect to moss and lichen cover.

Scalped plots released both more runoff water and more sediments than other treatments, but large within treatment variance rendered the results statistically nonsignificant for sediment loss (Table 11). As expected, control plots lost both less runoff water and less sediments than trampled plots, but large variances made it impossible to declare the results statistically significant. The three trampled treatments yielded essentially the same results for both water and sediment losses (Table 11). On the average, control plots released about 4% of the simulated rainfall, trampled plots (treatments 2-4 pooled) released roughly 64% of the applied water, and scalped plots released almost 81% of the simulated rainfall. In respect to soil erosion, control plots lost about 16% as much as trampled plots (three treatments pooled) and only 7% as much soil as the average scalped plots.

Since large variances and small sample sizes within treatments made most differences among treatments statistically nonsignificant by analysis of variance and Studentized Range tests (Snedecor and Cochran 1968), we used an alternative analysis for evaluation of the experimental results. Since values for both dependent (runoff volume and suspended sediment weight) and independent variables (cryptogamic cover, surface roughness, plot steepness, soil temperature, soil texture

Table 11. Runoff and soil losses from 0.25 m² runoff plots receiving 12.5 liters of water (equivalent) of 5.0 cm or 1.97 inches of rainfall) in an 8 minute period. Water was applied with an oscillating, pipette infiltrometer (Figure 4).

Treatment	Runoff (liters)	Soil loss (grams)
Control	5.28a ± 2.84	5.1a ± 5.1
Trample + water	7.92a ± 2.21	41.8a ± 44.9
Trample + water + chlorine	8.19a ± 1.05	17.1a ± 23.0
Trample	7.98a ± 0.95	35.0a ± 58.7
Scalped	10.12b ± 1.12	73.5a ± 72.4

and soil sodium content) were available for each of the 30 plots, interrelationships between dependent and independent variables were explored with simple linear regression (Table 11 and Table 12). Results show that total cryptogamic cover, lichen and moss cover alone and surface roughness each exerted a significant impact on runoff (Table 11). In all cases, plant cover and surface roughness decreased runoff. Sediment losses were significantly reduced by total cryptogamic cover and surface roughness and significantly enhanced by increasing volume of runoff water. Cryptogamic cover was apparently a more potent influencer of water runoff than of soil erosion, since r-values relating runoff to cover were consistently larger than those relating soil losses to cryptogamic cover (Table 11).

Discussion

Analysis of variance and Studentized Range tests are highly sensitive to within treatment variance and sample size within treatments. Time expenditures were so great per experimental plot that we could not accommodate a sample size of over 6 replicates per treatment in this study. As a result, most treatment effects could not be declared significantly different by conventional parametric tests such as ANOVA and the Studentized Range test. That was particularly frustrating for sediment loss analyses, since more soil was lost from the scalped than the control plot at each of the 6 subsites considered, yet those differences could not be declared significant because of large among site differences within a treatment class. The pattern was similar for control and trampled (three treatments pooled) treatments in respect to soil loss: in 15 of 18 cases, the trampled plots lost more

Table 12. Regression coefficients for the relationship of water runoff and soil loss (see Table 2 for values for various treatment conditions) to the independent variables of cryptogamic cover on soil surfaces, surface roughness, steepness of slope across runoff plots, soil temperature at time of infiltrometer trials, soil texture and amount of exchangeable sodium in the surface 2.5 cm of the soil at each plot. Average values for each independent variable in each of 5 treatments is given in Table 1. There were 30 observations considered for each regression analysis.

Variables Regressed	Regression Coefficient (r-value)	Significance ¹ Level for r- value
Runoff on		
Total cryptogamic cover	-.533	**
Algal cover only	-.340	NS
Lichen and Moss cover only	-.398	*
Surface roughness	-.679	**
Slope	-.180	NS
Soil temperature	+.047	NS
Soil sand	-.130	NS
Soil clay	+.180	NS
Soil sodium	-.320	NS
Soil loss on		
Total cryptogamic cover	-.362	*
Algal cover only	-.232	NS
Lichen and moss cover only	-.272	NS
Surface roughness	-.439	*
Slope	+.111	NS
Soil temperature	-.096	NS
Soil sand	-.101	NS
Soil clay	+.010	NS
Soil sodium	+.020	NS
Runoff	+.461	*

1. NS, not statistically significant; *, probability less than .05 that relationship is random; **, probability less than .01 that relationship is random.

soil than the control plot at the same site. The pattern was even more clear for runoff water: for that parameter, scalped plots always released more water than control plots at the same site and 17 of the 18 trampled plots lost more water than the control plot at a specific subsite.

Regression analysis increased sample size, since all plots could be used in the analysis giving 28 degrees of freedom instead of the 5 permitted for each treatment in the group comparison tests. Also the variation in runoff and sediment losses could be related in a continuous fashion to independent variables that varied within treatment groups but were not accounted for in the analysis of variance model used. As a result, regression analyses showed significance for the impact of plant cover and surface roughness (actually treatment effects) on runoff and soil loss.

Conclusions

The data demonstrate that cryptogamic crusts have a significant effect on water runoff and soil movement. The small size of our experimental plots makes it impossible to determine how far the eroded soil might be carried. There is, however, clear evidence that cryptogamic crusts and surface soil roughness that generally develops with the crusts reduces local runoff and soil movement. The effect is likely to influence regional soil stability and runoff as well.

OTHER RESEARCH ACTIVITIES

Artificial Establishment of Cryptogams

As one portion of this contract, Dr. St. Clair experimented with inoculation of disturbed soil surfaces with pulverized topsoil that contained the filaments and resting spores of bluegreen algae. The inoculum consisted of the surface centimeter of a soil that supported a well-developed crust consisting primarily of bluegreen algae with lesser amounts of common arid soil lichens (Collema and Caloplaca) and xerophytic mosses. The inoculum was collected when surface soils were desiccated. The sample was pulverized, suspended in distilled water and sprinkled over test plots. Control plots received only distilled water.

The trials were run at Mills, Millard County, Utah, near Oak Creek. A fire had removed the wood vegetation from a stabilized sand dune area there. A severe "blowout" had developed on the site following the fire. The inoculation trials were conducted on the sand blowout site.

Results demonstrate that bluegreen algae did establish vigorous cover on inoculated plots, while no significant change could be shown for control plots. Additional details can be obtained directly from Dr. St. Clair.

Cryptogams and the Nitrogen Cycle

In 1983, Steven J. Burns wrote a master's thesis in the Department of Agronomy at Brigham Young University entitled "Nitrogen Fixation and Transformation in Cryptogamic Soil Crusts as Affected by Disturbance." Steve's work was partially supported by this contract. Steve showed that nitrogen fixation was nearly completely lacking on burned rangeland soils without leguminous plants but was a measurable process on adjacent sites with intact cryptogamic crusts. Grazing also significantly

reduced nitrogen fixation in surface soils. He demonstrated that denitrification was an active process in desert soils when surface temperatures were over 10°C and the soils were wetted. Nitrogen fixation appeared to proceed at somewhat lower temperatures than denitrification; as a result, cryptogamic crusts generated nitrogen that was available to higher plants for several days prior to observance of rapid denitrification.

Evaluating Health of Lichen Thalli

The Ph.D. dissertation of Rebecca D. Fields was also partially supported by funds from this contract. Rebecca and Dr. St. Clair prepared a paper titled "A Comparison of Methods for Evaluating SO₂ Impact on Selected Lichen Species: Parmelia chlorochroa, Collema polycarpon and Lecanora muralis." It will be published in the next issue of The Bryologist. They developed a very sensitive method for detecting sublethal membrane damage to lichen thalli from SO₂, a common gaseous effluent from coal-burning industries. The method makes it possible to delimit, on the ground, the geographic extent of influences of toxic effluents from industrial plumes. The method has great value for predicting problem areas and for making adjustments in gaseous effluents permitted from specific point sources before the wastes destroy valuable biological sources.

Literature Cited

- Anderson, D. C., K. T. Harper, and R. C. Holmgren. 1982a. Factors influencing the development of cryptogamic soil crusts in Utah deserts. *J. of Range Manage.* 35:180-185.
- Anderson, D. C., K. T. Harper and S. R. Rushforth. 1982b. Recovery of cryptogamic crusts from grazing on Utah winter ranges. *J. Range Manage.* 35:355-359.
- Booth, W. E. 1941. Algae as pioneers in plant succession and their importance in erosion control. *Ecology* 22:38-359.
- Brotherson, J. D. and S. R. Rushforth. 1983. Influence of cryptogamic crusts on moisture relationships of soils in Navajo National Monument, Arizona. *Great Basin Naturalist* 43:73-78.
- Burns, Steven J. 1982. Nitrogen fixation in cryptogamic soil crusts. Master's thesis, Brigham Young University, Provo, Utah.
- Fletcher, J. E. and W. P. Martin. 1948. Some effects of algae and molds in the rain-crust of desert soils. *Ecology* 29:95-100.
- Kleiner, E. F. and K. T. Harper. 1972. Environment and community organization in grasslands of Canyonlands National Park. *Ecology* 53:299-309.
- Kleiner, E. F. and K. T. Harper. 1977. Soil properties in relation to cryptogamic ground cover in Canyonlands National Park. *J. Range Manage.* 39:202-205.
- MacGregor, A. N. and D. E. Johnson. 1971. Capacity of desert algae crusts to fix atmospheric nitrogen. *Soil Sci. Soc. of Amer. Proc.* 35:843-844.

- Rychert, R. C. and J. Skujins. 1974. Nitrogen fixation by bluegreen algae-lichen crusts in the Great Basin Desert. Soil Sci. Soc. Amer. Proc. 38:768-771.
- Schlatterer, E. F. and E. W. Tisdale. 1969. Effects of litter of Artemisia, Chrysothamnus, and Tortula on germination and growth of three perennial grasses. Ecology 50: 869-873.
- Snedecor, G. W. and W. G. Cochran. 1968. Statistical Methods, 6th ed. Iowa State University Press, Ames. 593 p.

BORROWER'S CARD

soil crusts on arid and semiarid
in Utah...

BORROWER	OFFICE	DATE RETURNED
ARID Lib	374344	12-16-89

(Continued on reverse)

Bureau of Land Management
Library
Bldg. 50, Denver Federal Center
Denver, CO 80225

